



m/019/005  
**Moab Salt, Inc.**

P.O. Box 1208 Moab, Utah 84532

Received  
9-28-89  
HCS

**Salt and Potash Production**  
(801) 259-7171

September 25, 1989

Mr. Lowell Braxton, Administrator

and

Mr. Holland Shepard, Reclamation Specialist  
State of Utah  
Department of Natural Resources  
Division of Oil, Gas and Mining  
355 West North Temple  
3 Triad Center, Suite 350  
Salt Lake City, Utah 84180-1203

Re: Mining and Reclamation Plan, Subsidence Report

Gentlemen:

In a letter dated January 28, 1988 from Mr. Lowell Braxton to Moab Salt, Inc. the Division of Oil, Gas and Mining addressed concerns it had with the original Mining and Reclamation Plan submitted for the Cane Creek Operation. Specifically discussed was subsidence. Item No.7, Page 2, of "Attachment A, Items Required" stated:

We will require that Moab Salt demonstrate that subsidence will not be a problem over the 100-year mine life or commit to subsidence monitoring.

With recent staff changes at Moab Salt, it was determined that an engineering study of the potential surface effects of mine subsidence would be necessary. Such a study conducted by a competent outside consulting firm using available historic mine data would provide the company and DOGM with an understanding of subsidence over the mine's life.

It is the company's position that this study as completed by Schnable Engineering and Associates has accomplished this goal. The study, using state-of-the-art engineering techniques and proven personal experience, goes well beyond demonstrating that subsidence over the Cane Creek Mine will have negligible surface effects. All predicted amounts of surface subsidence will be extremely difficult to detect and are well beyond the capabilities of the method recommended by Scott Johnson's internal memorandum to Holland Shepard dated September 7, 1989.

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To further address these recent concerns outlined in the above-referenced memorandum, Moab Salt has had Schnable Engineering personnel prepare a follow-up document. Attached is their report where they specifically address each point raised in the State's document. Moab Salt also provides further discussion on some of the same points below.

Company reports and verbal communications from previous employees of the Cane Creek Operation indicate that <sup>1.04</sup> injection/extraction should be maintained at 1.04. This ratio allows for maintaining a "static" mine opening. In other words, salt creep into the mine openings equals the volume of salt removed by solution mining. <sup>gallons</sup> <sup>gallons</sup> <sup>in</sup>

Historically, the injection/extraction ratio has been below the 1.04 needed to maintain a constant mine volume. Therefore, mine closure is slowly taking place and salt creep is reducing the open mine working's volume by filling them. Solution mining and subsequent removal of the salt are not keeping up with salt creep. It stands to reason then that the lateral expansion of the mine is not taking place. Rather the mine perimeter is shrinking.

Mine closure at the end of converted underground mining has been roughly estimated to be  $\pm 30\%$  from rock mechanics reports. Deep pumpdowns were also practiced in the past to improve recovery. However, each pumpdown resulted in a 1 to 1-1/2% decrease in mine volume. The deeper the pumpdown, the larger percentage of closure.

Development wells, in the past, have been drilled directionally to within  $\pm 20$  feet of the mine's perimeter. Their purpose was to expand the mine laterally. It was concluded that these efforts were unsuccessful, as they were unable to make a hydrologic connection with the old mine workings.

Currently, a high sodium brine is being injected so that potash can be selectively mined. This reduces the solution's ability to migrate outside of the mining zone.

References have been made by staff members, and others, to a surface subsidence program conducted by Texasgulf. To the best of our knowledge, a program was conducted in the years 1976, 1977, 1978 and 1980. The results of the program are of questionable value, however.



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Moab Salt is willing to further discuss this information with the Division at any time. In order to fully understand the work by Schnable Engineering, it would be beneficial if its representatives were also present at such a meeting. Once again, we believe that the reports prepared by Schnable Engineering Associates, dated August 2, 1989 and September 20, 1989, adequately "demonstrate that subsidence will not be a problem over the 100-year mine life."

Sincerely,

A handwritten signature in dark ink, appearing to read "C. Alan Tapp". The signature is fluid and cursive, with the first name "C." and last name "Tapp" clearly distinguishable.

C. Alan Tapp  
Technical Services Manager

CAT/mp



September 20, 1989  
Our Ref. UT890955

Mr. C. Alan Tapp  
Moab Salt, Inc.  
P.O. Box 1208  
Moab, Utah 84532

Subject: Review of State of Utah  
Comments dated September 7, 1989  
and Additional Subsidence Analyses

Dear Alan,

We have reviewed the State of Utah comments on our Subsidence report dated August 2, 1989. We have also completed additional analyses that address the State's concerns.

The State expressed much concern about the subsidence issue in general, and appeared to be most concerned about the potential effects on the Colorado River. They also are concerned that the solution mining activities may be removing virgin materials from outside the current mining limits which could increase the potential for mine subsidence.

To address these issues, we have performed additional analyses and completed some additional investigations. In order to examine the potential subsidence effects on the Colorado River, we have examined the mined zones closest to the river and calculated the predicted subsidence profile for a "worst case" condition. Figure 1 shows the locations of the profiles that were examined. Figures 2 and 3 presents the cross sections representing the profiles. Of the three cross sections shown, cross section C-C' is the most critical (i.e., would have the greatest effect on the river). From the C-C' in Figure 3 cross section

shown, we have calculated an idealized subsidence profile using the procedure outlined in the Subsidence Engineers Handbook (1975). Although this method was developed for longwall coal mining, data on salt-mine subsidence indicates that the method is generally applicable to salt mining for the reasons outlined in our previous report. It is important to understand, however, that the predicted subsidence profile obtained from this method should be considered as an order of magnitude of expected subsidence rather than an absolute value.

For this analysis, we evaluated the potential subsidence along cross section C-C', shown in Figures 1 and 3, using the following assumptions:

Depth to mining	3000 feet
Mined Height	8 feet
Extraction Ratio	100 %
Average width of mining panel	800 feet
Average length of mining panel	2100 feet

The average width of mining was conservatively selected since the section nearest the river is only about 300 feet wide. At the northwest end of the cross section the mined width increases considerably. Subsidence from this area, however, will not substantially effect the area of interest (i.e., the Colorado River). Overall, we consider the analysis performed to provide a "worst case" evaluation of potential subsidence across the Colorado River.

The results of the subsidence analyses are shown in Figure 3. This figure shows the profile of the predicted total vertical displacement above the mining horizon in the direction of the river. The lateral boundaries of predicted subsidence extend approximately 2200 feet from the edge of mined zone, reaching a point approximately 1500 feet east of the Colorado River. Review of Figure 3 indicates that the maximum predicted subsidence at the Colorado River ranges between 0.3 to 0.5 inches. Again, the subsidence values calculated should be considered as order of magnitude estimates that

suggest the total subsidence at the river should be less than one-inch. Since this subsidence will occur over an extended period of time and much of the subsidence has probably already occurred, it is hard to envision any substantial effect on the Colorado River. Calculation of horizontal strain and tilt was considered unnecessary given the nature of this problem.

The States' second concern seemed to center on the effects of solution mining on the extraction of pillars and possible expansion into virgin salt. Although, perhaps not completely clear in our previous report, we predicted the maximum subsidence above the zones depicted in our report assuming a final 75% extraction ratio and 10 feet of virgin salt removed from the perimeter of the mining areas. The 75% extraction ratio was provided to us by Moab Salt and based on their production records from the solution mining. The maximum predicted subsidence under these conditions was about seven inches. Even if a "worst case" 100 percent extraction was assumed, the maximum predicted subsidence would not increase by more than one-third or to a maximum of about nine inches. Since these numbers should again be considered as order of magnitude estimates, this analysis suggests that maximum subsidence over the panels will be in inches and not in feet and that total maximum subsidence in the area should be less than a foot. Again, much of this subsidence has probably already taken place over the past 20 years and future subsidence may be difficult to measure.

We consider the assumption of 10-feet of virgin salt removed from the mine perimeter to be a reasonable estimate of materials removed since solution mining was initiated. The solution mining records clearly indicate that the pillars are being removed. Since the pillars have two to four times more exposed area per linear foot than the ribs, they should be removed much quicker than the virgin salt exposed along the perimeter. When roof collapses occur, the salt in the collapsed material will be dissolved. Some re-routing of the flow paths adjacent to virgin salt as a result of collapse or closure will likely occur, however, it is our opinion that the dissolution zones will not be sufficient to increase

surface subsidence significantly and has already been accounted for in our analysis. Of interest on this subject are the unsuccessful attempts of Moab Salt to develop solution wells that are within 10 to 20 feet of mine workings. These wells were drilled but could never be opened to the mine workings to allow active solutioning to begin. This indicates that, at least in the areas of drilling, the virgin salt had not been dissolved greater than 10 to 20 feet into the ribs which is consistent with our assumption.

The State is also recommending the use of 2-foot contour aerial photography to detect subsidence. This recommendation is not, in our opinion, reasonable for the conditions at the site. The maximum predicted subsidence is less than 1-foot over the mined areas. Since the accuracy of a 2-foot contour map is only  $\pm 1$ -foot, it is hard to envision that subsidence could be detected by this method. Our staff has, in the past, attempted to use this method to analyze subsidence above coal mines in Colorado, salt mines in New Mexico, and limestone mines in Missouri. Our experience indicates that subsidence on the order of 2 to 4 feet is required for this method to be successful. As a result, we cannot, given the predicted subsidence magnitude, concur with the State on the recommendation to perform this work.

Finally, the State is requiring a subsidence monitoring network. They indicate that a previous network exists over the area. We have no record of such a network, although we are aware of some unreliable elevations taken on well heads that were subject to large vertical variations with well head pressure. Given the magnitude of the predicted subsidence and that much of the subsidence has probably already occurred (the State apparently concurs with this), a very precise level survey would be required to measure subsidence. It is our opinion that such a network is unnecessary unless some indication of detrimental effects from surface subsidence begins to be observed at the surface.

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We hope this data provides you with the information you need. We would be happy to discuss this further with either you or the State if additional questions arise.

Sincerely,  
SCHNABEL ENGINEERING ASSOCIATES, P.C.

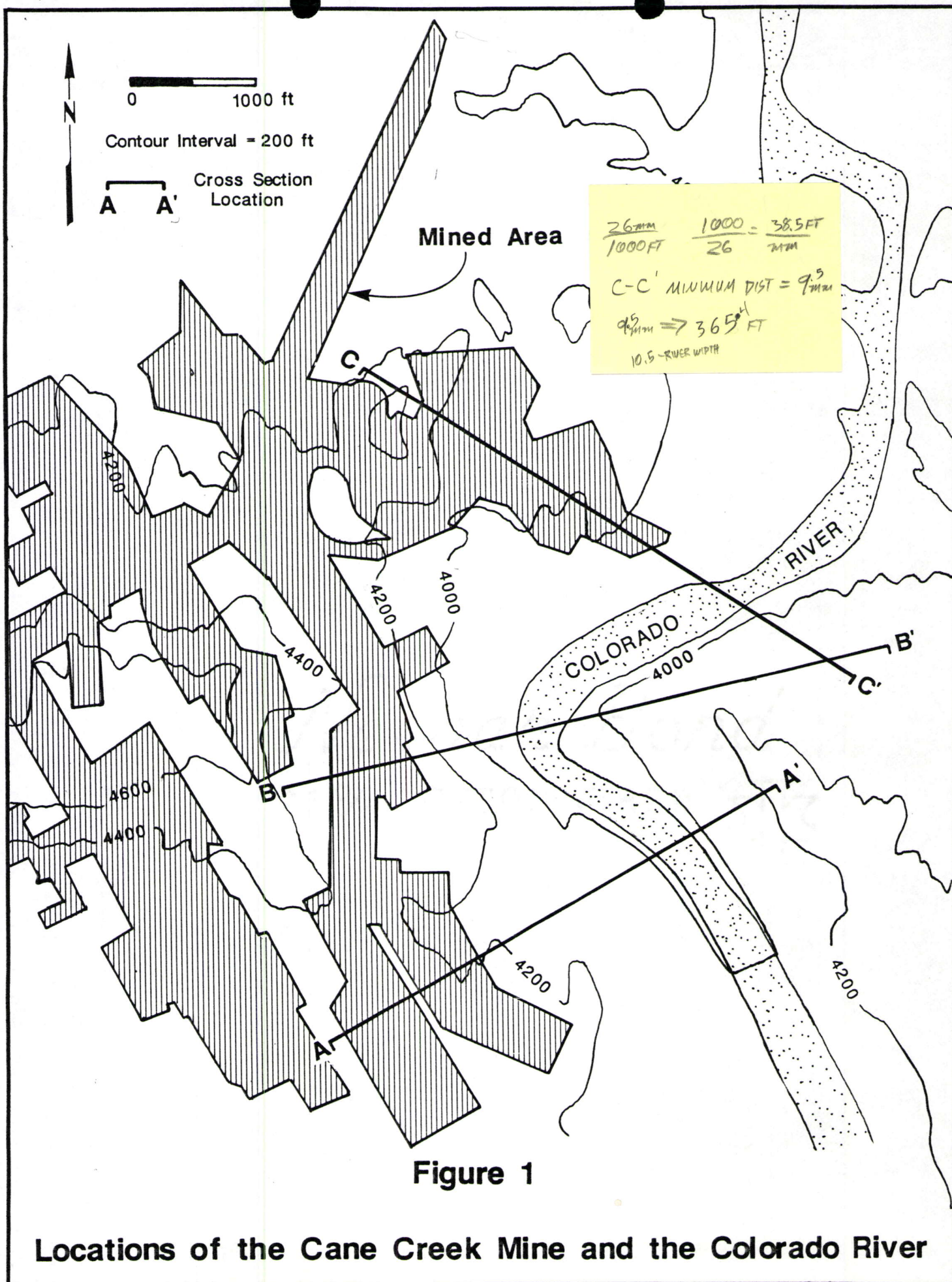
*Gordon M Matheson / ENC*

Gordon M. Matheson, Ph.D., P.E.  
Senior Associate

GM/sn

enclosure





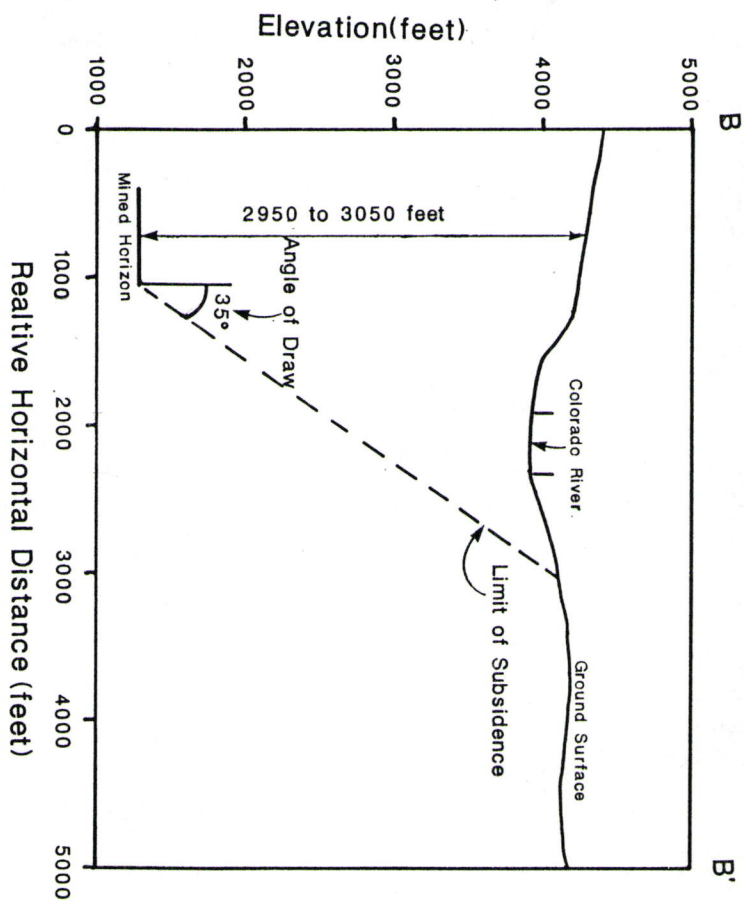
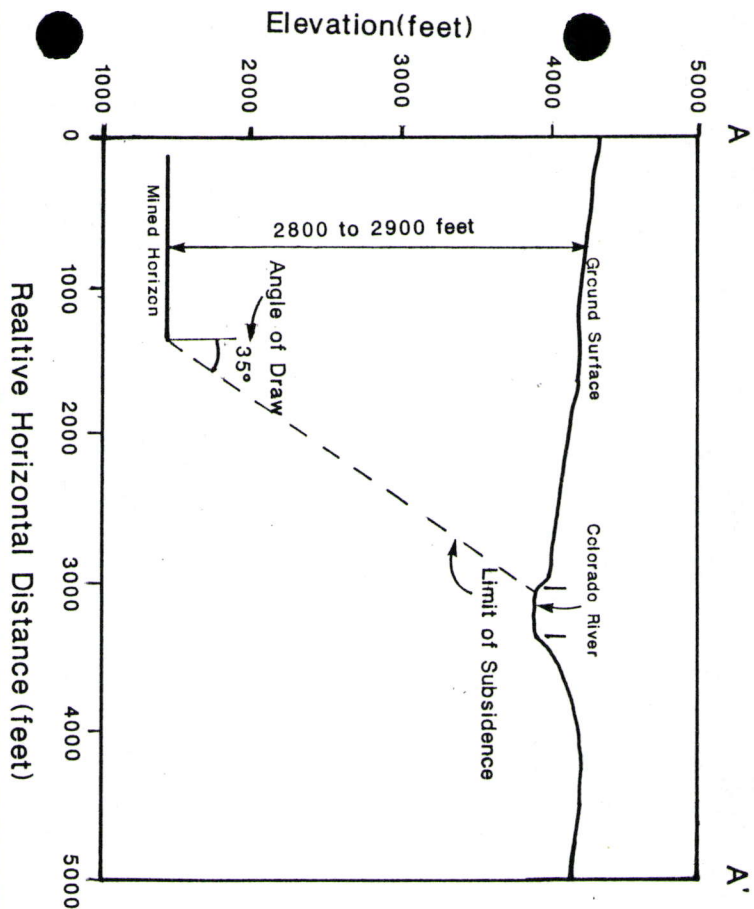
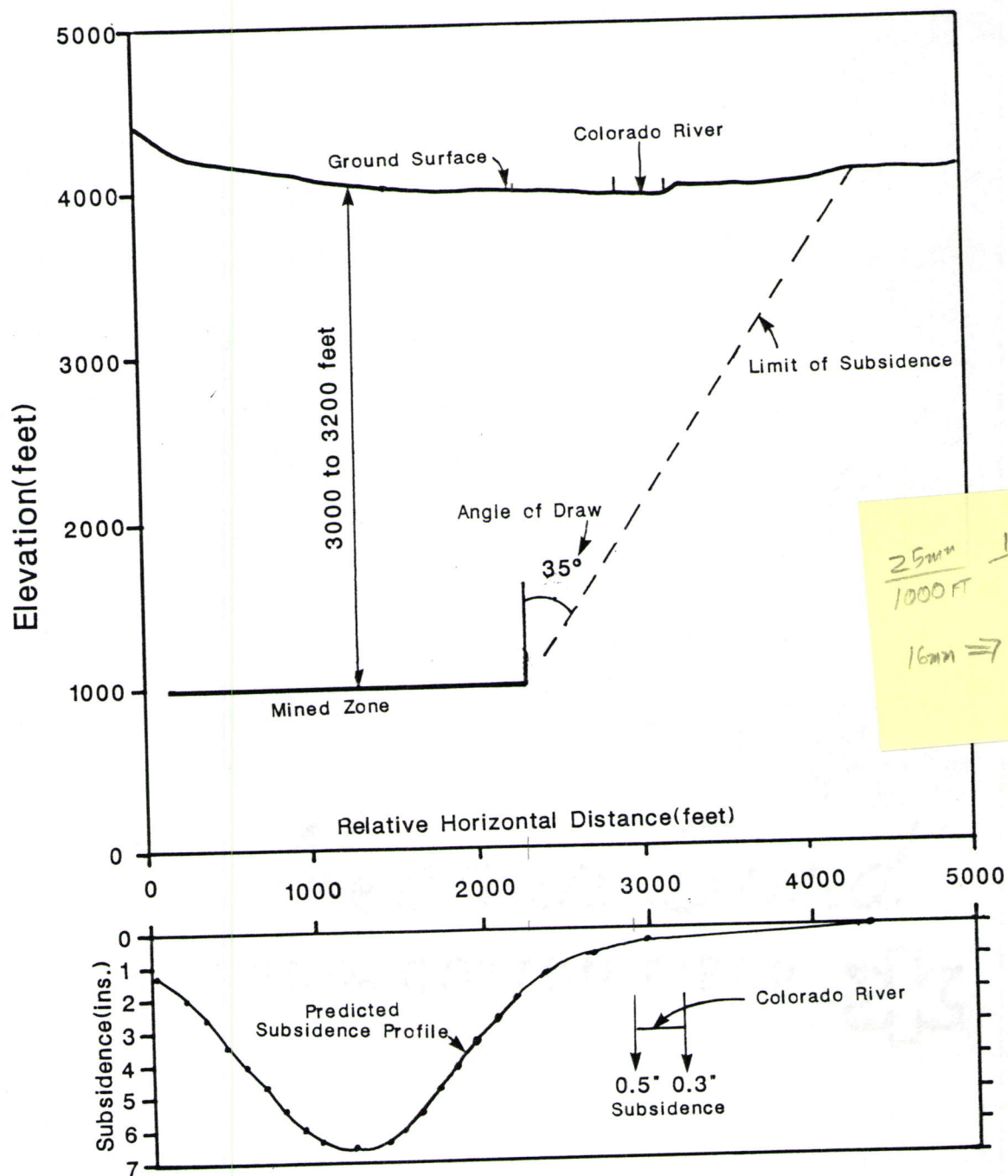


Figure 2

Typical Cross Sections A-A' and B-B'

See Figure 1 for Location of Cross Sections

how was 35° AdD  
determined? (This is  
somewhat higher than  
used for Ut. Coal  
mines)



**Figure 3**  
**Cross Section C-C'**  
**and**  
**Predicted Subsidence Profile**